

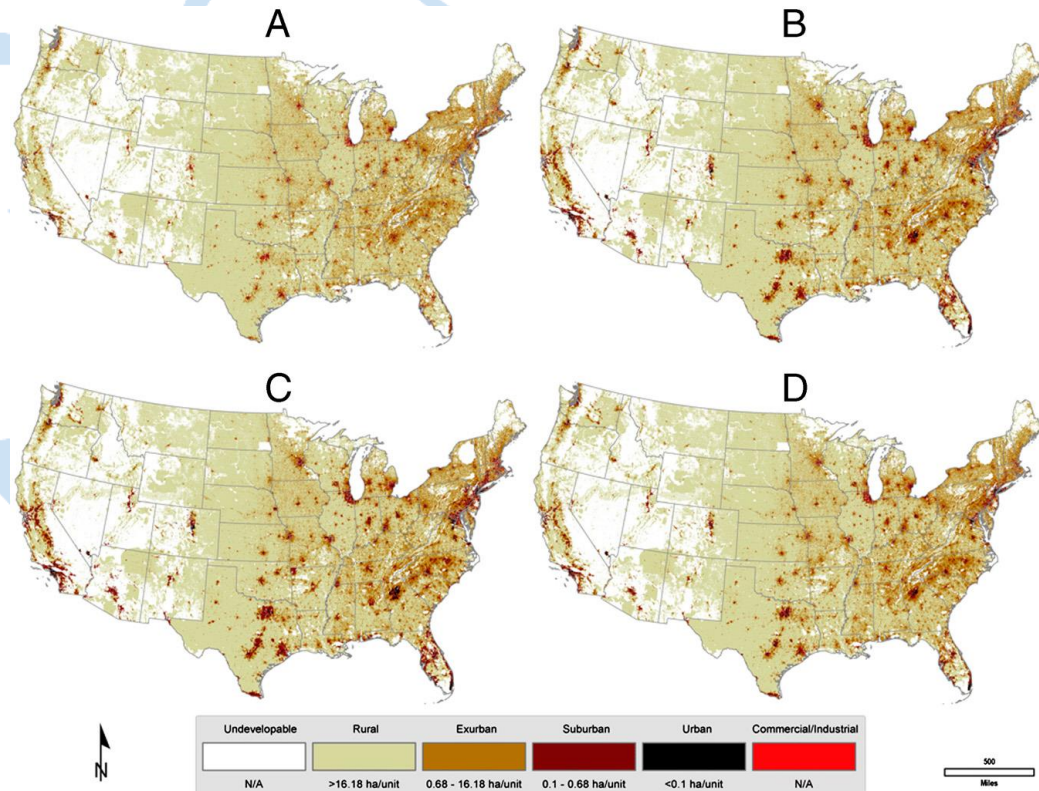
Integrated Climate and Land Use Scenarios

From population to land use/cover:
demand → allocation → effects,
challenges & opportunities

David M. Theobald^{1,2}

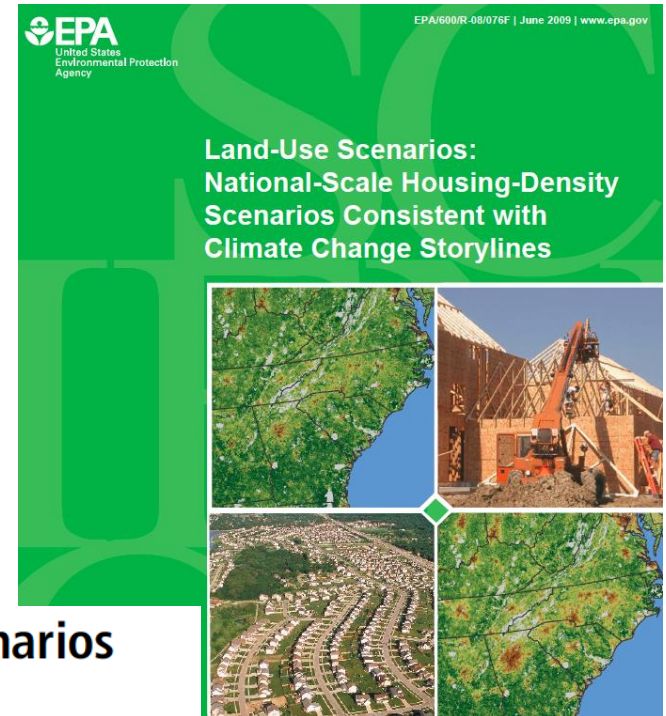
¹Conservation Science Partners

²Department of Fish, Wildlife, and
Conservation Biology, Colorado
State University



Co-authors

Britta Bierwagen, Phil
Morefield, John Thomas,
Jonathan Witt, EPA
Phil Groth and Anne Choate, ICF
Chris Pyke, USGBC



National housing and impervious surface scenarios for integrated climate impact assessments

Britta G. Bierwagen^a, David M. Theobald^{b,1}, Christopher R. Pyke^c, Anne Choate^d, Philip Groth^d, John V. Thomas^e, and Phil

^aGlobal Change Research Program, 1200 Pennsylvania Avenue, Ecology Lab, Colorado State University
^cICF International, 1725 Eye Street, Economics, and Innovation, US E

Edited by Lawrence E. Band, University of

Understanding the impacts of

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Theobald, D. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecology and Society* 10(1): 32. [online] URL: <http://www.ecologyandsociety.org/vol10/iss1/art32/>

Research

Landscape Patterns of Exurban Growth in the USA from 1980 to 2020

[David M. Theobald¹](#)

PNAS



Percent change 2000-2100

150%
100%
50%
0%
-50%

A1

A2

B1

B2

BC

Urban

Exurban

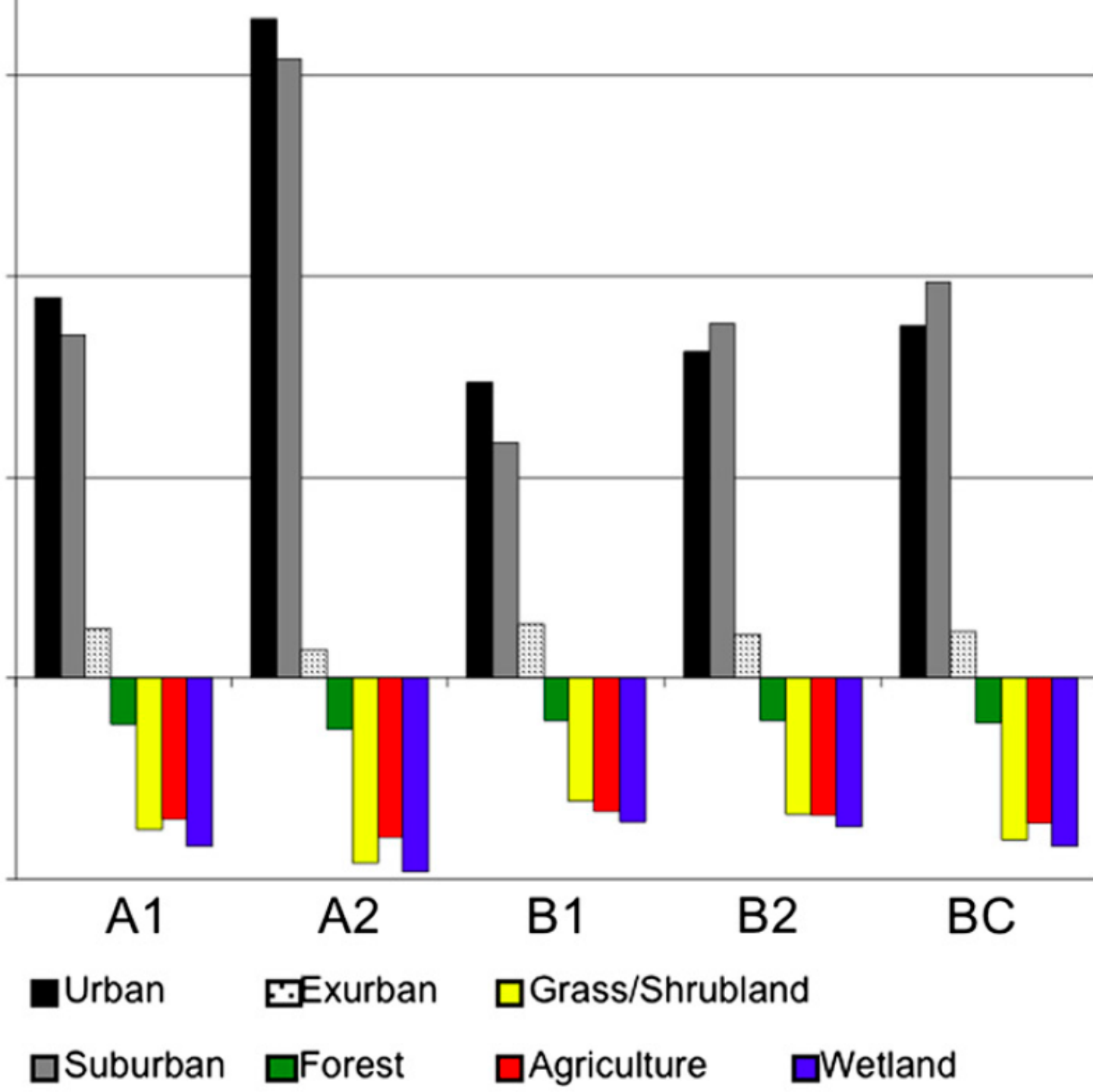
Grass/Shrubland

Suburban

Forest

Agriculture

Wetland



Road map

Discuss feasibility of producing land use/cover forecasts from population projections

1. Demand → allocation, coupling models
2. Translating scenario descriptions to tangible parameters
3. Scaling issues
4. Challenges/opportunities

Approach: loosely-coupled (sequential)

Demography (cohort-component)

- age, gender, race/ethnic specific
- Domestic migration using functional-based gravity model
- Population estimated

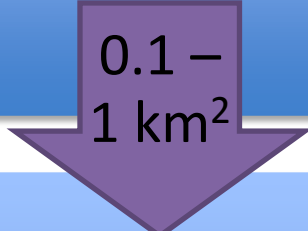
county



Spatial allocation (SERGoM)

- Hierarchical deterministic, emergent
- Residential housing density

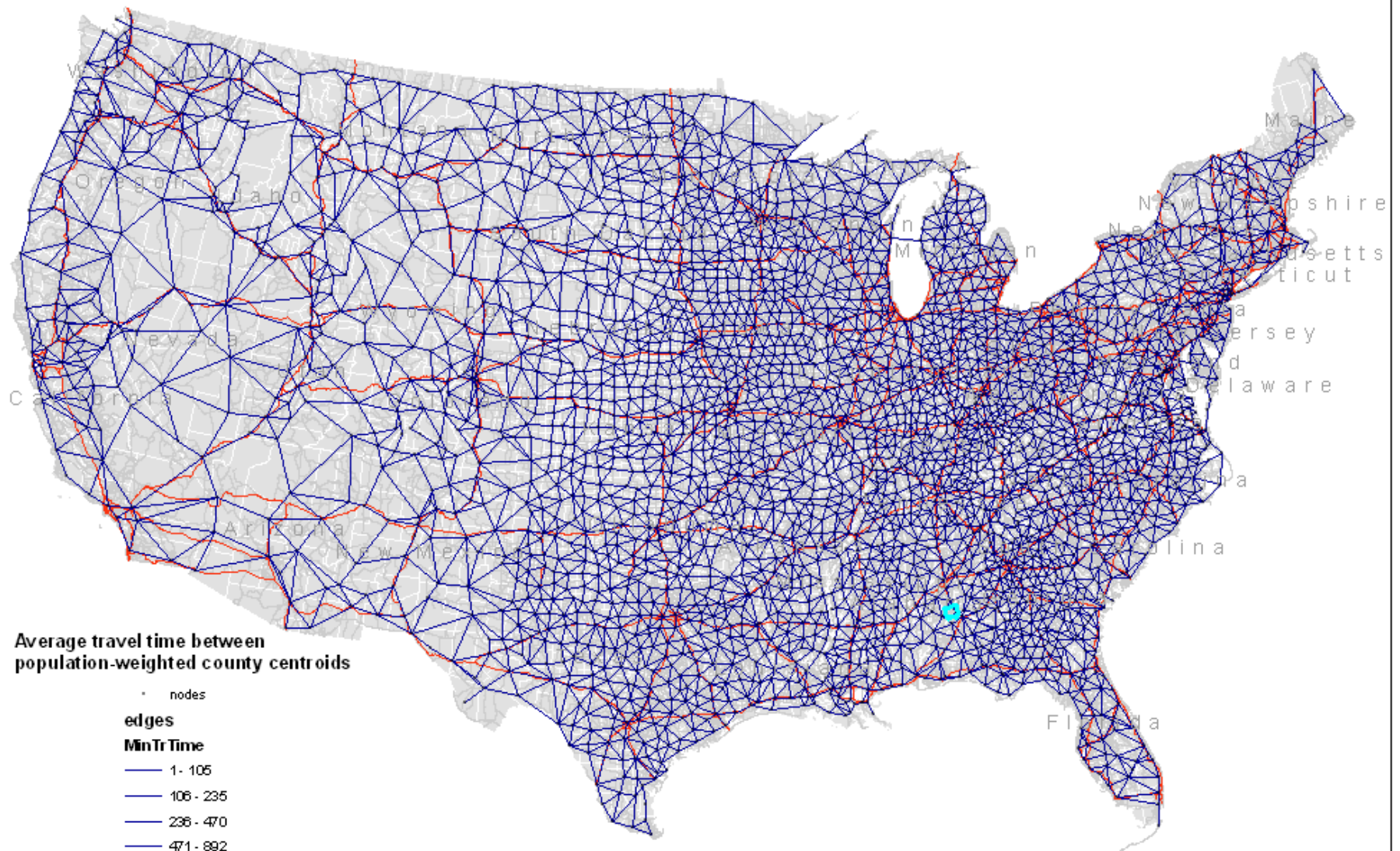
0.1 –
1 km²



Effects/impacts

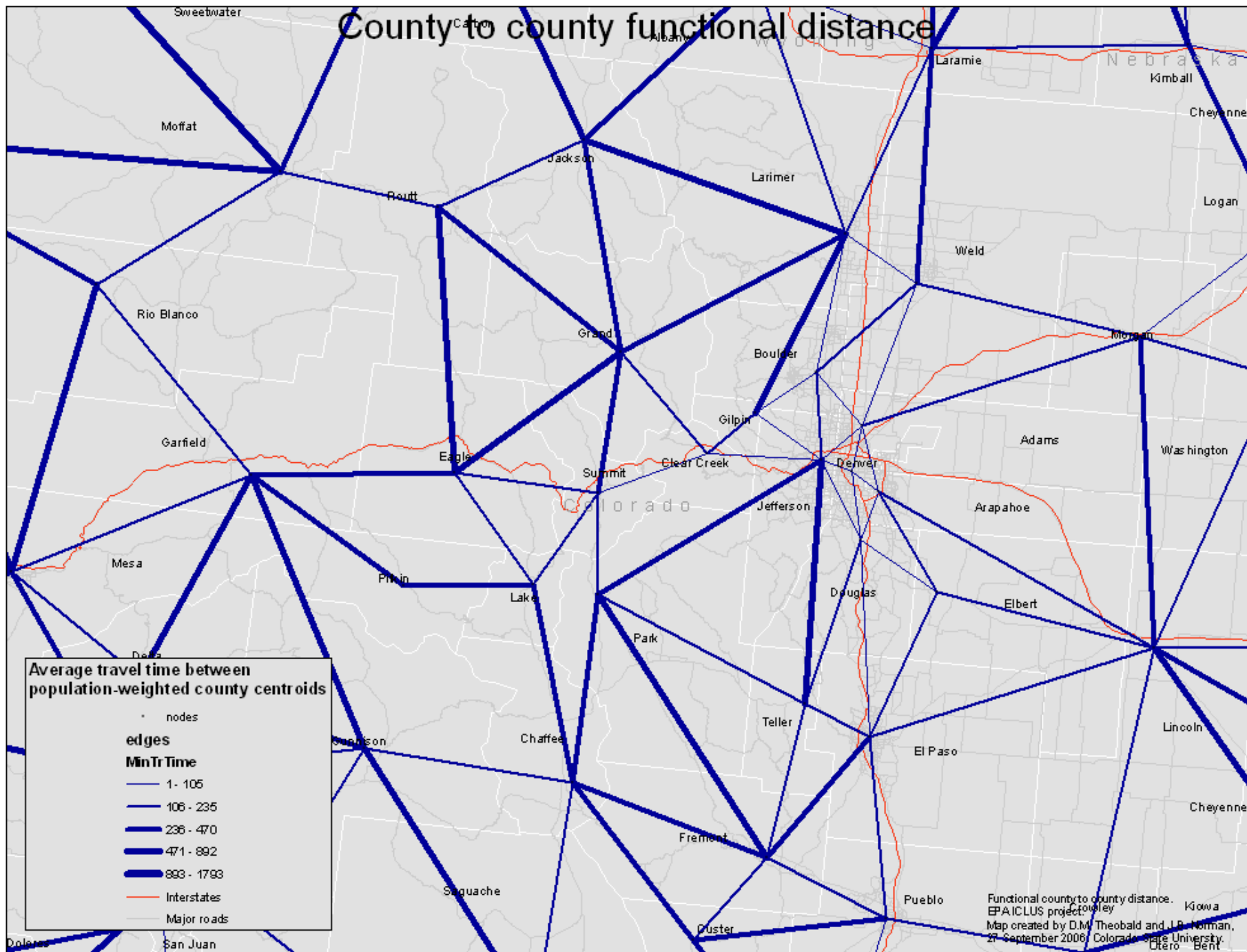
- impervious surface
- Wildlife habitat, connectivity, etc.

County to county functional distance



Functional county to county distance.
EPA/ICLUS project.
Map created by D.M. Theobald and J.B. Norman,
27 September 2006. Colorado State University.

County to county functional distance

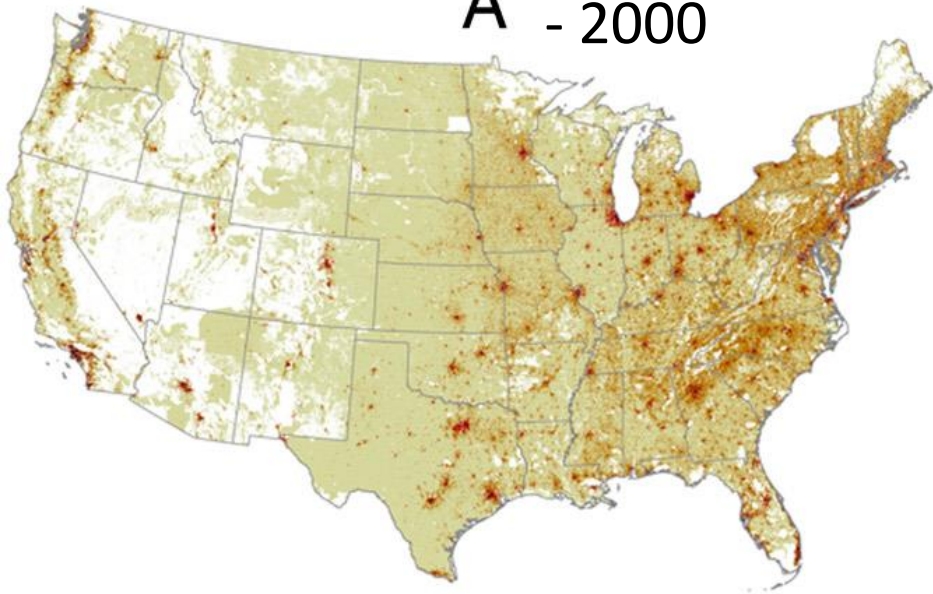


Spatially Explicit Regional Growth Model

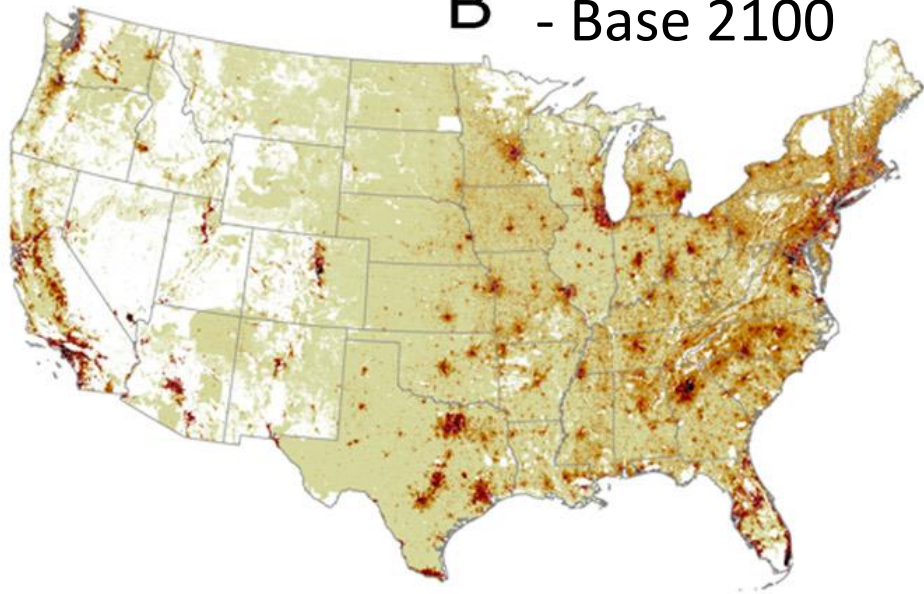
SERGoM v1



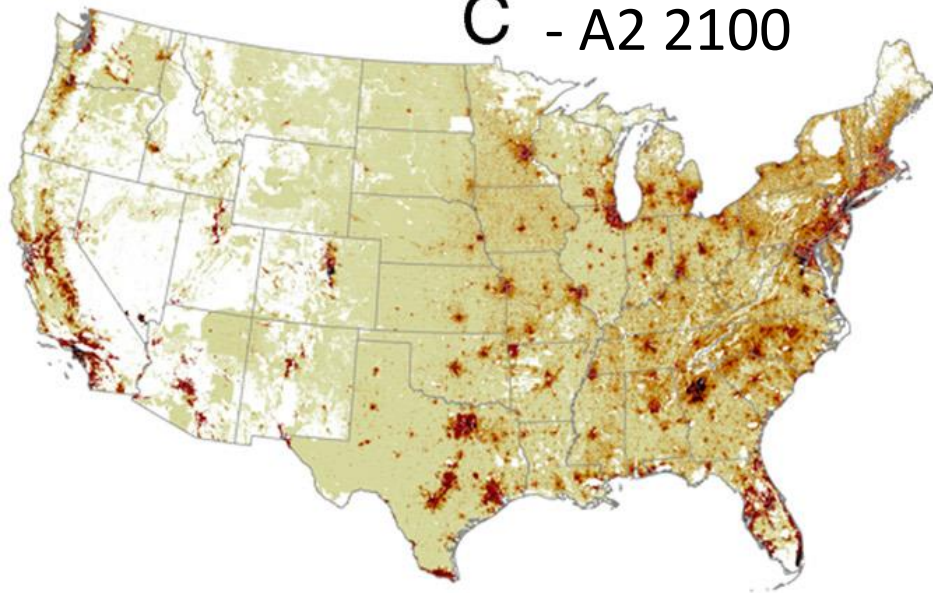
A - 2000



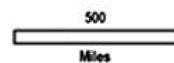
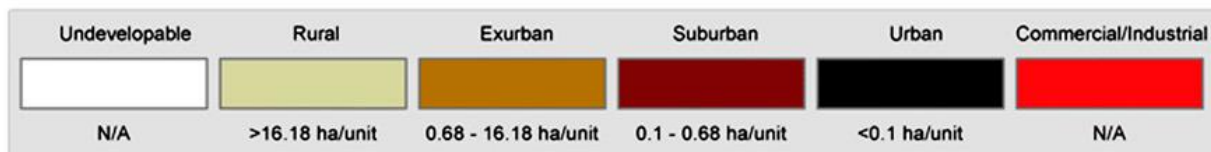
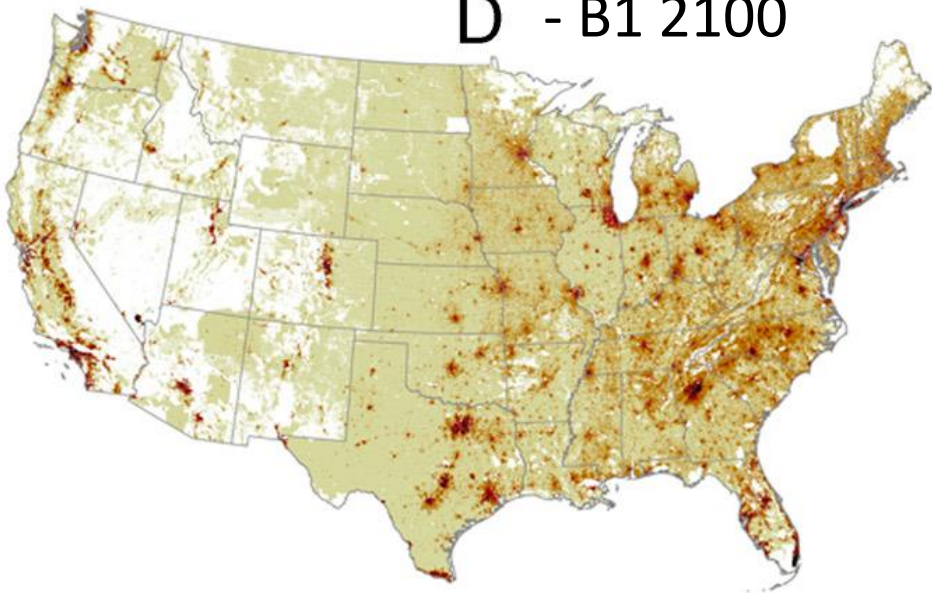
B - Base 2100



C - A2 2100



D - B1 2100



Spatial allocation

- Census block-level housing 1990, 2000
- Travel time (accessibility along major transportation infrastructure from urban areas – dynamic)
- Weights based on proportion of NLCD cover
 - Developed open space: 0.085
 - Developed (22-24): 0.55
 - Transitional: 0.115
 - Wildland vegetation: 0.15
 - Agricultural: 0.05
 - Wetlands: 0.05
- Groundwater wells (important in rural areas)
- Spatial parameters (layers) for growth rate as a function of housing density and accessibility

Scenarios to parameters

Sce- nario	Fertility, mortality, migration	Household size	Travel time
Base	Medium, low, medium	0%	~2000
A1	Low, low, medium	-15%	Dispersed
A2	High, high, high	+15%	Dispersed
B1	Low, low, medium	-15%	Compact
B2	Medium, medium, medium	0%	Compact

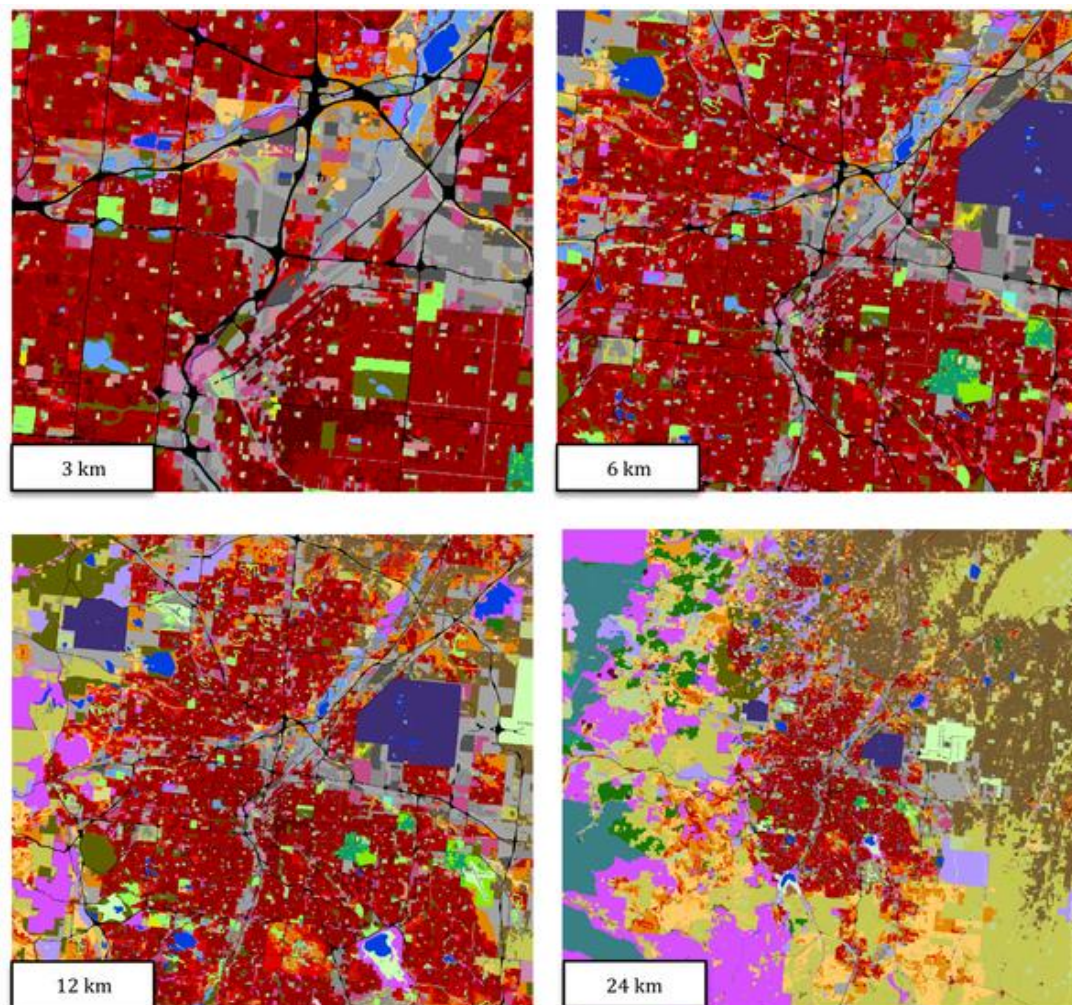
Scaling issues

- Thematic/intensity (classes)
 - Residential density
 - Nod to commercial/industrial, public/undeveloped
 - Assume development (not decline, restoration, removal)
- Extent
 - Designed for: regional (multiple counties/states)
 - International flows (esp. Mexico, Canada)?
 - Local (County): e.g., county growth, park interface, etc. (~1-5 km buffers)
- Analytical unit/grain
 - County boundaries – “capping” growth, spill-over
 - Spatially-explicit: 1 ha - 1 km² impervious surface
 - Trade-offs: higher resolution vs. fewer classes
 - Estimating impacts needs high resolution, intensity and pattern
- Temporal
 - Past predicts future? Out for 100 years?
 - Continuous or abrupt

Improvements to ICLUS

- Updated datasets (CMIP 3, IRS, Census, Transportation)
- Demographic model uses changing climate variables
- Allocation from residential density to land use types
- Transportation: travel time to capacity; fixed-guide transit

Figure 6. The National Land Use dataset for 2010 centered on Denver, Colorado (I-25 and I-70), showing NLUD at 4 different scales.



Theobald DM (2014) Development and Applications of a Comprehensive Land Use Classification and Map for the US. PLoS ONE 9(4): e94628.

doi:10.1371/journal.pone.0094628

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0094628>

From 2000 (rows) to 2010 (columns)	Water	Wetlands	Recreation-conservation	Timber	Agriculture grazing	Agriculture pastureland	Agriculture cropland	Extractive mining	Parks/open space	Exurban low	Exurban	Suburban	Urban medium	Urban high	Commercial	Industrial and utility	Institutional	Transportation
Water	x	Y ND	N ND	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Wetlands	Y ND	x	N ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Recreation-conservation	N	N	x	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND
Timber	N	Y ND	Y ND	x	Y	Y	Y	Y ND	Y ND	Y	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Agriculture grazing	N	Y ND	Y ND	Y	x	Y	Y	Y ND	Y ND	Y	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Agriculture pastureland	N	N	Y ND	Y	Y	x	Y	Y ND	Y ND	Y	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Agriculture cropland	N	N	Y ND	N	Y	Y	x	Y ND	Y ND	Y	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Extractive mining	N	N	Y ND	N	N	N	N	x	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND
Parks/open space	N	N	N	N	N	N	N	Y ND	x	Y ND	Y ND	N	Y ND	Y ND	Y ND	Y ND	Y ND	Y ND
Residential (exurban low)	N	N	N	Y	Y	Y	Y	Y ND	Y ND	x	Y	Y	Y	Y	Y	Y	Y ND	Y ND
Residential (exurban)	N	N	N	N	N	N	N	Y ND	Y ND	Y	x	Y	Y	Y	Y	Y	Y ND	Y ND
Residential (suburban)	N	N	Y ND	N	N	N	N	Y ND	Y ND	Y	Y	x	Y	Y	Y	Y	Y ND	Y ND
Residential (medium)	N	N	Y ND	N	N	N	N	N	Y ND	Y	Y	Y	x	Y	Y	N	Y ND	Y ND
Residential (high)	N	N	Y ND	N	N	N	N	N	Y ND	Y	Y	Y	Y	x	Y	N	Y ND	Y ND
Commercial	N	N	Y ND	N	N	N	N	N	Y ND	Y	Y	Y	Y	Y	x	Y	Y ND	Y ND
Industrial and utility	N	N	Y ND	N	N	N	N	Y ND	Y ND	Y	Y	Y	Y	Y	Y	x	Y ND	Y ND
Institutional	N	N	Y ND	N	N	N	N	Y ND	Y ND	N	N	Y ND	Y ND	Y ND	Y ND	Y ND	x	Y ND
Transportation	N	N	Y ND	N	N	N	N	N	Y ND	N	N	N	N	N	N	N	N	x

			KEY:						
			Y	Yes, reasonable chance of transition					
			Y ND	Yes, reasonable chance of transition, BUT temporal change					
			N	No, not a reasonable chance of transition					
			N ND	No, not a reasonable chance of transition, AND temporal change					
			x	no transition (same class)					
				Transitions implemented in SERGoM v2					
				No transitions should occur in SERGoM v2					

Code	Group	Class Name
0	Water	Lake/river
1		Reservoir/canals
2		Wetlands
3	Protected	Recreation/conservation
4	Working / Production	Timber
5		Agriculture grazing
6		Agriculture pastureland
7		Agriculture cropland
8	Built	Mining/barren
9		Parks, golf course
10		Residential (exurban low)
11		Residential (exurban)
12		Residential (suburban)
13		Residential (medium)
14		Residential (high)
15		Commercial
16		Industrial and utility & <u>misc</u>
17		Institutional
18		Transportation

Feasibility/practicalities

Reviewers	Refinements	Difficulties
Incorporate spatial dynamics (emergent behavior)	Transit, transportation capacity	Micro-scale behavior (walkability, TOD); Update capacity (limited data)
Represent urban land use transitions	10 classes of urban land use; based on transitions	Poor model behavior using empirical transition probabilities (vs. internal consistency)
Incorporate market effects (economy)	Directional transitions	Deterministic model vs. stochastic simulation (interpretation, computational)
Patterns depend on local-scale dynamics	Land use classes; 30-90 m resolution	Computational limits; Mixed use (esp. commercial/resid.)
Integrate drivers (top-down and bottom-up)	7 Regions; states; counties Iterate through ordered land uses	Uniqueness of county growth; Computational limits

Challenges/opportunities

- Population is key (but there's more...)
 - permanent residential vs. secondary, transient
 - links with residential (also employment & economies)
 - $\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology}$
 - Climate effects mediated by affluence & technology
- Multiple land use types (beyond “development”)
 - Developed (residential)
 - Developed (commercial/industrial/transportation)
 - Resource (Ag., timber, mining, etc.)
 - Recreation/conservation
- Urban counties dominate growth patterns (but rural areas important too!)
 - Low-density residential beyond urban fringe
 - Interface with: wildlands, prime farmland, wetlands/water
- Transportation & accessibility (cover type or flow between uses?)
 - From static (2000 or 2010) to dynamic
 - How to identify urban? Distance from what, to what?
 - Distance to accessibility to capacity
 - Evolution of transportation networks (increase capacity vs. expanding into frontiers)
 - What's the next Interstate Highway system?

Thanks!

Comments, questions?

- Feedback: davet@csp-inc.org
- Conservation Science Partners:
www.csp-inc.org
- Landscape & Climate Change
Vulnerability Project:
<http://www.montana.edu/lccvp/>
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